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RESEARCH ARTICLE

Mobile-based system for collecting data on tree health status in field protective forest belts in southern Dobrudzha, Bulgaria

Lyubomira Georgieva[1], Veselin Ivanov[2], Margarita Georgieva[2], Yonko Dodev[2], Georgi Georgiev[2]

[1]*Sofia University 'St. Kliment Ohridski', Faculty of Geology and Geography, Department of Cartography and GIS*
[2]*Forest Research Institute – Bulgarian Academy of Sciences*

Corresponding author: Margarita Georgieva (margaritageorgiev@gmail.com)

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Abstract

In southern Dobrudzha, northeastern Bulgaria, a system of field protective forest belts (FPFBs) was established in the 1950s to reduce wind speed, prevent soil erosion, retain soil moisture, improve microclimate, and increase agricultural yields. Most FPFBs are located within the territories of the State Hunting Enterprise (SHE) Balchik and State Forest Enterprises (SFEs) General Toshevo and Dobrich. Since 2020, the health condition of the FPFBs has significantly declined. In this study, a mobile system based on ArcGIS Field Maps from ESRI, compatible with Android and iOS, was developed. It includes 31 specific fields for assessing the health status of trees in FPFBs, collecting data from fieldwork, and transferring it to electronic records. Between June and August 2024, the system was tested by evaluating the health status and damage of trees in 190 FPFBs across SHE Balchik, SFE General Toshevo, and SFE Dobrich. The advantage of our web-based data collection system is its ability to export data immediately to Excel and formats like CSV, KML, and GeoJSON. It also reduces field data entry time, improves data security, and allows for the inclusion of specific photos of tree damage.

Keywords

Field protective forest belts, health status, monitoring, online platform, ArcGIS Field Maps, southern Dobrudzha, Bulgaria

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Introduction

In northeastern Bulgaria, a system of field protective forest belts (FPFBs) was established in the 1950s, covering 10695.5 hectares to reduce wind speed, protect soil from wind erosion, maintain soil moisture, improve the microclimate, and increase the fertility of agricultural lands (Dodev et al., 2023; Georgieva et al., 2024). Most of the FPFBs (7886.2 hectares) are located within the territories of the State Hunting Enterprise (SHE) Balchik, the State Forest Enterprise (SFE) General Toshevo, and SFE Dobrich in southern Dobrudzha (Dodev et al., 2023). Since 2020, a significant decline in the health status of the tree vegetation in the FPFBs has been investigated (Georgieva et al., 2024). Based on the studied stand's characteristics, the experience gained in forestry science and practice, an original methodology for a comprehensive assessment of the condition of the FPFBs was developed (Dodev et al., 2025).

Monitoring data are crucial for evaluating forest health (Potočić et al., 2021). Mobile devices such as smartphones and tablets are effectively used in forestry to measure tree diameter at breast height, tree height and volume, location, etc. (Fan et al., 2020; Magnuson et al., 2024). Traditionally, forest management and assessment were labor-intensive, requiring extensive on-the-ground surveys and manual data collection. However, advances in satellite imagery and mobile apps have transformed how we manage trees. Now, we can gather accurate data and assess tree health and condition remotely, saving time and resources (GIS People, 2025). Mobile apps are vital for continuous data collection, and integrating this data into electronic records quickly is highly desirable.

Geographic Information Systems (GIS) have become a vital component of data management, analysis, and presentation across many research fields (Milanes et al., 2014). GIS allows for quick integration of multiple data sets and acts as a tool for making informed decisions. It is a type of information system that includes computer hardware, software, a database, and users, designed for inputting, storing, manipulating, analyzing, and retrieving geographic data to support various tasks in areas such as environmental management, transportation, demography, public administration, and business (Popov, 2012). According to Popov (2012), the development of GIS shows that, unlike its use in the 1970s, which was mainly for computer-based cartography, in the early 21st century, the focus shifted toward integrating geospatial technologies (such as GPS, remote sensing, and GIS) and adopting modern solutions like virtual reality and mobile applications.

The term 'mobile GIS' refers to using geographic information systems on mobile devices such as smartphones, tablets, or a global navigation satellite system (GNSS) receivers for collecting, storing, updating, visualising, and analysing spatial data directly in the field and accessing it remotely. Advances in mobile and handheld devices, like smartphones, tablets, and GPS units, have introduced new capabilities for field GIS data collection and sharing. With the rapid growth of mobile and computer technologies, wireless communications, and the widespread use of mobile devices and cloud services, mobile information technologies are becoming increasingly important in everyday life. Location-Based Services, which rely on accurate positioning, easy

communication, and data transfer, are now more common than ever. Precise description and localization of objects are crucial in ecological studies, and traditional methods of positioning and recording are gradually being replaced by modern digital tools. Among these, mobile mapping devices and applications are gaining significant popularity. Specialized portable GPS receivers are now mostly replaced by smartphones with built-in GPS modules, making field mapping much easier and accessible to a broader range of users (Nowak et al., 2020).

The study aimed to present a mobile-based system developed to collect data from field studies in FPFBs and transfer it to electronic records without a direct connection.

Methodological approach

Used platform

The mobile system was developed based on the ArcGIS Field Maps platform from the Environmental Systems Research Institute, Inc. (ESRI), suitable for Android and iOS. The choice of ArcGIS Field Maps was based on its integrated support for spatial data collection, detailed mobile forms, and cloud synchronisation, all of which are essential for recording multiple indicators of forest health. Despite the growing availability of mobile mapping tools, many studies still overlook them when describing field methods (Nowak et al., 2020).). The authors argue that environmental scientists could significantly improve their data collection and workflow by adopting mobile GIS applications, as these tools offer better accuracy and more efficient data recording. As a result, this platform was particularly suitable for the complex structure of the database, which requires accurate positioning, photo attachments, and consistent attribute entry.

In forestry fieldwork in some countries, the devices most commonly relied upon for positioning are smartphones together with other low-cost GNSS receivers. Smartphones dominate this category owing to their ease of use, mobility, and wide range of integrated features (Huang et al., 2022). According to the authors, although survey-grade GNSS devices perform best in forested environments, smartphones – especially dual-frequency models, can still achieve good accuracy of about 2.5 m in open forest areas.

In addition to ArcGIS Field maps, several other mobile GIS platforms have been successfully applied in environmental and forestry studies, including QField and SW Maps. These applications provide similar functionalities such as offline data collection, attribute editing, and field-ready map display.

Transition to mobile data collection

The database structure was created from a carnet and transferred to an online version so that the data in the field was filled on the mobile phones. This allowed all required attributes to be accessed directly on mobile devices, enabling field teams to enter data in real time instead of relying on paper notes.

Conceptual scheme and work process

A conceptual scheme (Fig. 1) provided a structured overview of the steps undertaken to develop the mobile-based system. The research team held several planning meetings to organise the tasks, determine the necessary field work, and identify the most appropriate criteria for assessing tree health status. ArcGIS Field Maps was chosen as the platform for collecting the required data. The database structure was developed in advance (Table 1).

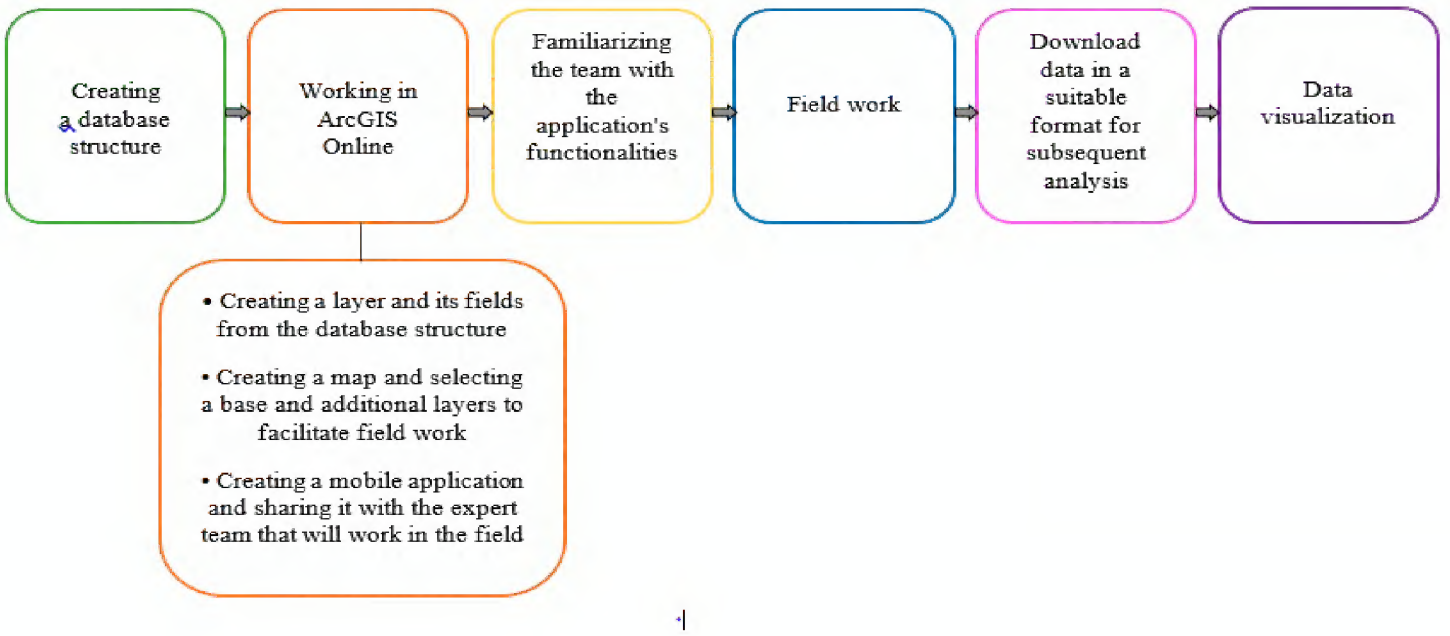
Creating a database structure
Working in ArcGIS Online
Familiarizing the team with the application's functionalities
Field work
Download data in a suitable format for subsequent analysis
Data visualization
• Creating a layer and its fields from the database structure
• Creating a map and selecting a base and additional layers to facilitate field work
• Creating a mobile application and sharing it with the expert team that will work in the field

Fig. 1. A conceptual scheme presenting the work process.

After the database structure was created, it was implemented in a GIS environment using ArcGIS Online. ArcGIS Online is a cloud-based geographic information system that offers a wide range of functionalities, including: creation of web maps; use of ready-to-deploy resources; publication of map services; execution of spatial analyses; sharing of data; access to maps from different devices; and serving as a foundation for developing custom applications with geospatial functionality (Kholoshyn et al., 2019).

A layer called 'Health status' was created, and the database structure was implemented with its attribute fields. After creating the fields we wanted to fill in, we specified the data type – what we wanted to input – such as text (including the character limit if the data type is text), a numerical value, a drop-down list with predefined options, or an attached file.

After creating the layer, a map was generated that included the specific layer, an appropriate basemap, and other layers useful for field work. In this case, the additional layer was a polygon layer with digitized boundaries of the SHE Balchik, SFE General Toshevo and SFE Dobrich, along with their labels. The map uses the World Imagery basemap, which provides global satellite coverage and high-resolution aerial imagery. It was selected because it is the only basemap where the belts and our location relative to them are clearly visible.

ArcGIS Online served as a platform that supported the process of collecting field data through integration with Esri's ArcGIS Field Maps mobile application. This application functions as an effective fieldwork tool that replaces traditional localization methods, such as specialized GNSS devices, and manual data entry on paper.

Field study

The field survey includes an assessment of the general condition of each belt (SHE/SFE, Unit, Subunit, Tree/shrub species, Preservation, Defoliation, Coloration, Damages etc.).

Application interface

ArcGIS Field Maps is an all-in-one app that uses data-driven maps and mobile forms to assist workers in capturing and editing data, locating assets and information, and reporting their real-time positions (Fig. 2) (https://www.esri.com/en-us/arcgis/products/arcgis-field-maps/overview).

The symbol for a collected point, once we gathered its coordinates, such as those of individual trees, was a white tree displayed against a green background. A point was marked by pressing the 'plus' button, after which the necessary fields to fill in appeared. Once a point was already collected, a so-called pop-up appeared with information about it, allowing us to open the captured or attached photo.

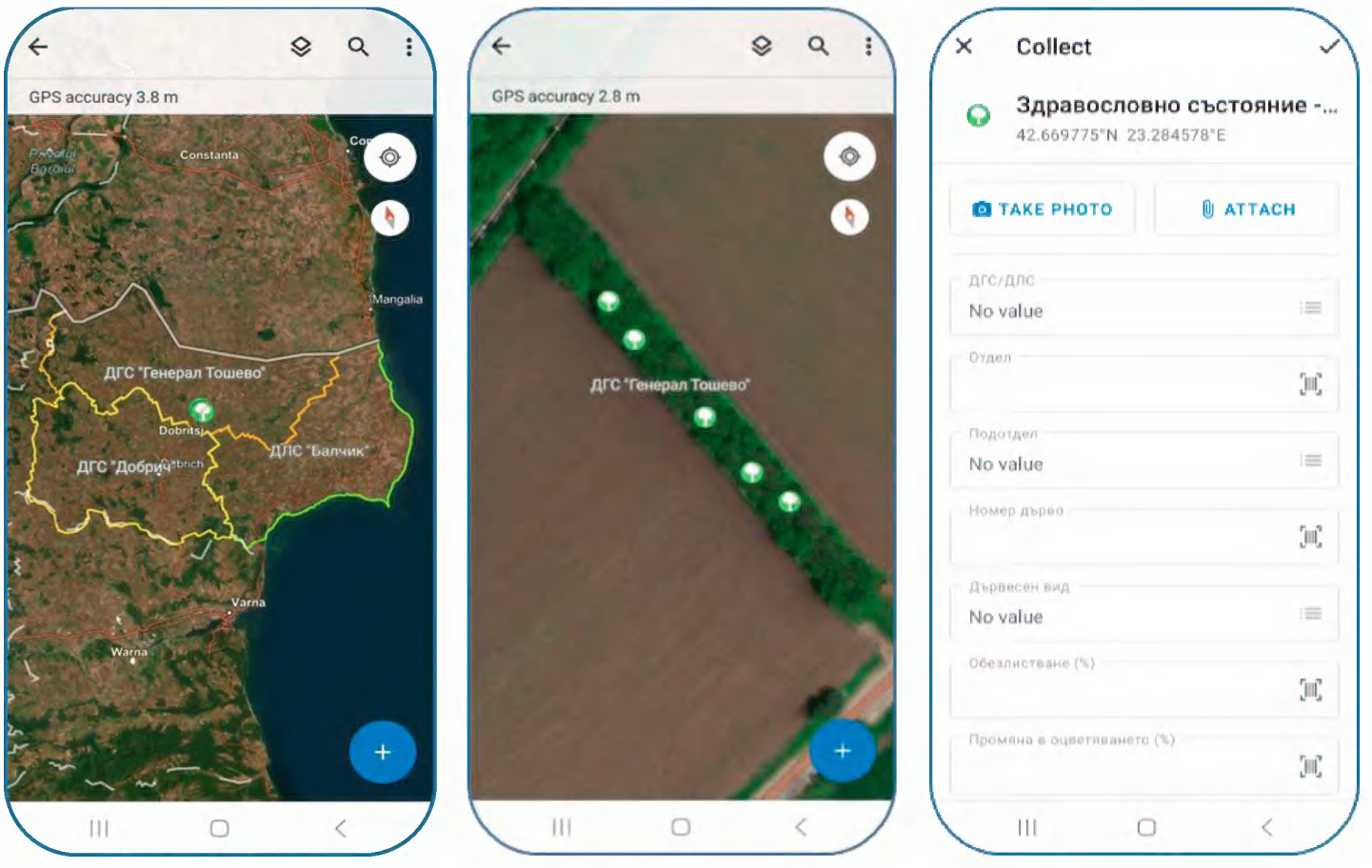

Fig. 2. Application interface: assessed trees (left and middle); indicators (right).

Health status assessment

For assessing the health status of tree species, 31 fields were filled out (Table 1).

Table 1 contains six columns and shows the fields that were used for analysis and were filled in on-site, as follows:

- **Field name** – the names of the fields in the database;
- **Display name** – the names of the fields as they appear in the mobile application while collecting data on site;
- **Data type** – whether it is text, numeric, date or attached file;
- **Drop-down list** – whether the fields are filled in via drop-down menus (Y = Yes), described in a separate table;
- **Length** – the allowed length of characters for filling in for text data type;
- **Description** - a more detailed description of what is filled in by the expert on site.

Table 1. Studied characteristics of tree health status in FPFBs.

N N	Field name	Display name	Data type	Drop-down list	Length	Description
1	**OBJECTID**	OBJECTID	ObjectID			Automatically filled in by the application identification number for each tree
2	**dgs_dls**	SFE/SHE	String	Y	256	State Forestry and hunting Enterprises in the studied territory (Table 2)
3	**Section**	division	Integer			Division of the field protective forest belt (according the forestry inventory) in which the tree is located
4	**Subdivision**	Subdivision	String	Y	10	Subdivision of the field protective forest belt (according forestry inventory) in which the tree is located (Table 2)
5	**Tree_number**	Tree number	Integer			Tree number filled in by a person in the field
6	**Tree_species**	Tree species	String	Y	256	Tree species selected from a drop-down menu in Bulgarian and Latin (Table 2)
7	**Preservation**	Dominant tree species preservation (degree)	String	Y	256	To what extent is the dominant tree species preserved in the field protective forest belt (Table 2)
8	**Preservation_ percent**	Preservation (%)	Integer			What is the percentage of preservation of the dominant tree species in the field protective forest belt

9	**Permeability**	Belt ventilation	String	Y	256	What is the degree of ventilation of the field protection zone (Table 2)
10	**Defoliation_ percent**	Defoliation (%)	Integer			Specific percentage of the absence of leaves on the tree from the entire crown
11	**Coloration_ percent**	Color change (%)	Integer			What is the specific percentage of leaves that have a change in normal color
12	**Stems_ percent**	Stem damage (%)	Integer			What part of the stem is damaged, calculated in percentages
13	**Drying_ percent**	Drought (%)	Integer			What part of the crown is affected by dry rot, calculated in percentages
14	**Drying_ descr**	Drought (description)	String		1000	More free text description about drylands
15	**Antr_stem_ percent**	Anthropogenic stem damage (%)	Integer			What part of the stem is damaged by anthropogenic factors, calculated in percentages
16	**Antr_stem_descr**	Anthropogenic stem damage (description)	String		1000	More free text description about anthropogenic damage to the stem
17	**Antr_branch_ percent**	Anthropogenic branch damage (%)	Integer			What part of the branches is damaged by anthropogenic factors, calculated in percentages
18	**Antr_ brannch_descr**	Anthropogenic branch damage (description)	String		1000	More free text description about anthropogenic damage to the branches
19	**Abiotic_dam_ percent**	Abiotic damage (%)	Integer			What part of the tree is damaged by abiotic factors, calculated in percentages
20	**Abiotic_dam_ descr**	Abiotic damage (frost cracks / snowfall/icebreakers/hail/fires/ other)	String		350	More free text description about abiotic damage to different parts of the trees
21	**Biotic_stem_ percent**	Biotic damage to stems (%)	Integer			What part of the stem is damaged by biotic factors, calculated in percentages
22	**Biotic_stem_ descr**	Biotic damage to stems (description)	String		1000	More free text description about biotic damage to stems
23	**Biotic_ branch_ percent**	Biotic damage to branches (%)	Integer			What part of the branches are damaged by biotic factors, calculated in percentages

24	**Biotic_ branch_descr**	Biotic damage to branches (description)	String		1000	More free text description about biotic damage to branches
25	**Biotic_leaves_ percent**	Biotic damage to leaves (%)	Integer			What part of the leaves are damaged by biotic factors, calculated in percentages
26	**Biotic_leaves_ descr**	Biotic damage to leaves (description)	String		1000	More free text description about biotic damage to leaves
27	**Biotic_root_ percent**	Biotic damage to roots (%)	Integer			What part of the roots are damaged by biotic factors, calculated in percentages
28	**Biotic_root_ descr**	Biotic damage to roots (description)	String		1000	More free text description about biotic damage to roots
29	**Notes**	Notes	String		5000	Add additional records for which there are no fields, but would be important for completeness of the data
30	**Date**	Date	Date			Date and time of collection of the specific point
31	**Photos And Files**	Photos And Files	Attachment			Attached photos taken at the moment or previously taken

Table 2. Drop-down lists options.

Field name	**Drop-down list options**
dgs_dls	SHE Balchik
	SFE Dobrich
	SFE General Toshevo
Subsection	a - k
Tree_species	*Acer campestre*
	Acer platanoides
	Acer pseudoplatanus
Preservation	well preserved (≥ 70%)
	partly preserved (50 - 70%)
	poorly preserved (< 50%)
Permeability	permeable
	open-worked
	impermeable

The health condition of trees in the studied FPFBs was evaluated by estimating the level of defoliation in 40 trees compared to the foliage on a standard reference tree (Eichhorn et al., 2020). Crown defoliation serves as an indicator of tree health and vitality, and has been linked to reduced growth and an increased likelihood of tree death. The defoliation of individual trees was measured, and average scores were

categorized as mild, moderate, or severe damage based on defoliation levels and the presence of crown dieback.

An excellent advantage of collecting data using mobile GIS is that it is recorded immediately after collection. It can be downloaded in various formats depending on the tasks and analyses that need to be performed afterward. It can be saved as a purely tabular form, like an Excel spreadsheet, or in shapefile and .kml formats for spatial visualization, which allow you to display geographic features on a map. It is important that the collected data was saved with its pair of coordinates – *x* and *y* (Table 3).

Table 3. Collected data in Excel Table.

1. OBJECT	2. SFE/SHE	3. Unit	4. Sub-unit	5. Tree_number	6. Tree_species	7. Preservation	30. Date	x	y
1	Dobrich	479	a	1	*Quercus rubra*	well preserved	2024-09-05	27.7313	43.6539
2	Balchik	2322	a	1	*Quercus rubra*	well preserved	2024-09-05	28.4323	43.5097
3	Balchik	2322	a	2	*Quercus rubra*	well preserved	2024-09-05	28.1269	43.5847
4	Balchik	2429	a	1	*Fraxinus americana*	partially damaged	2024-05-15	28.2878	43.4842
5	Balchik	2429	a	2	*Fraxinus americana*	partially damaged	2024-05-15	28.2878	43.4842
6	Balchik	2429	a	6	*Fraxinus americana*	partially damaged	2024-05-15	28.2878	43.4842
7	Balchik	2429	a	3	*Fraxinus americana*	partially damaged	2024-05-15	28.2878	43.4842

Data visualisation

Data visualisation was carried out using the ArcGIS Online platform, which allows users to create interactive dashboards that combine spatial and statistical data visualization with numerous configuration options and analytical tools (Fig. 3). A dashboard functions as a graphical interface designed to display key metrics and indicators, making it easier to analyze processes or applications. In the context of Geographic Information Systems, such dashboards are used to present spatial data in a more interactive and insightful manner.

ArcGIS Dashboards offers various tools such as charts, graphs, indicators, lists, and gauges, which can be combined and linked through actions to support dynamic data analysis (Bhatia et al., 2019).

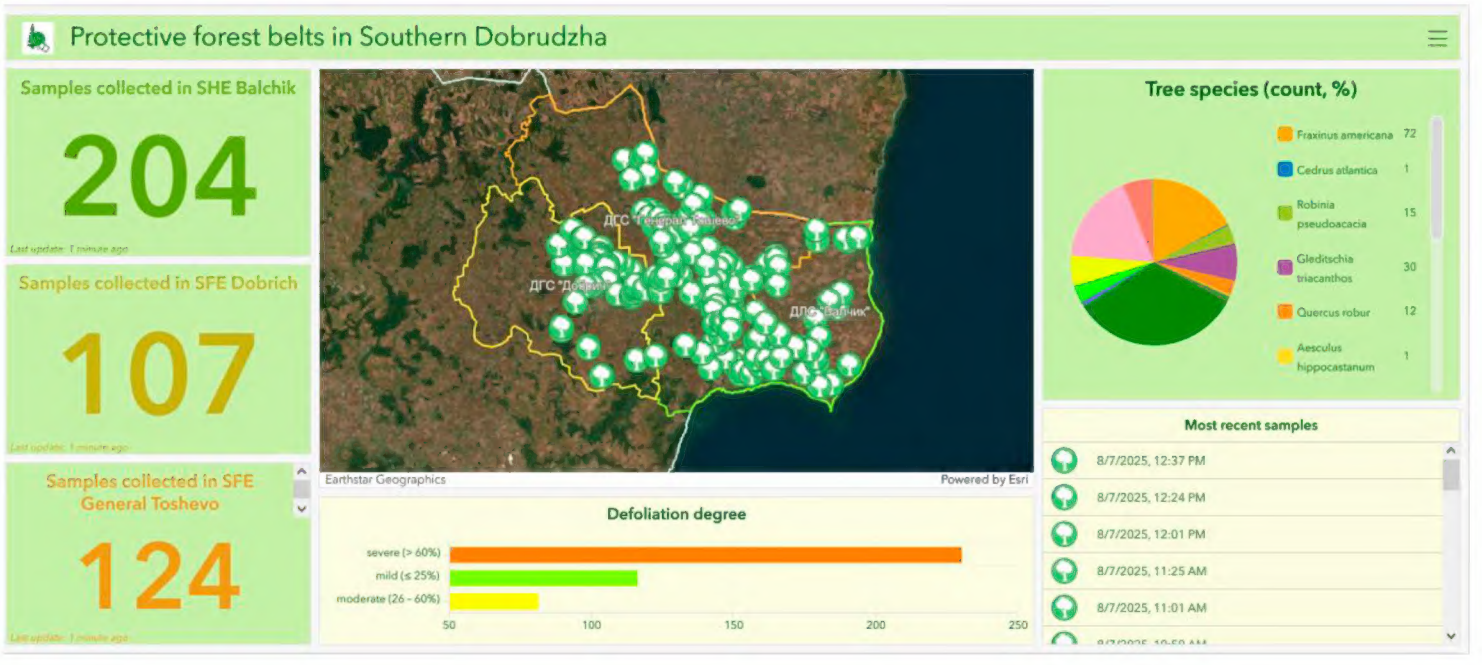

Fig. 3. Created dashboard.

One of the main functionalities of the dashboard is the interconnectivity between visualizations. When a specific element is selected, the values in most components, such as lists, charts, and maps, are automatically updated. This enables targeted and detailed exploration of each category or individual feature.

The dashboard also offers real-time data updates. Any changes made during fieldwork, such as adding new features or editing existing ones, are automatically reflected in the dashboard. This method of data presentation ensures real-time visualization and quick access to the most recent data.

Conclusions

Collecting data on the health status of trees in the field protective forest belts through the developed mobile-based system provides the following advantages:

- The ability to export to Excel immediately after data collection, which in turn increases the speed of uploading data in electronic form, since otherwise it would have to be filled out on paper in the field and then everything would have to be entered manually into Excel;
- The possibility of exporting to other formats – CSV, KML, GeoJSON etc.;
- The time for filling in data in the field is reduced - after experience in the field, filling in data takes about 2-3 minutes per tree;
- Security in data storage – they are immediately saved in the cloud in the online space;
- Better orientation on the map, which shows our location at all times;
- The ability to add photos – coordinates are recorded on paper, but they may have about 1 or 2 meters of deviation, so photos help when a person returns to the same zone and wants to re-evaluate the same tree, he will have not only the coordinates, but also photos, which will help to recognize the tree, as they also contribute to the completeness of the data.

During the field testing, 190 FPFBs were surveyed and a total of 7600 individual trees were recorded using the mobile system, demonstrating its practical functionality in large-scale monitoring. The average time per entry was 2–3 minutes per tree, confirming a significant reduction compared to traditional paper-based methods. The ability to collect georeferenced photos for each tree greatly improved the consistency of re-identification during follow-up assessments and enhanced the completeness of the dataset.

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